

Efficacy of Neuromuscular Control Training Combined with Intro-articular Injection for Rotator Cuff Tears with Concomitant Shoulder Stiffness in Elderly Patients

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Abstract:

Background: Few studies have discussed the management of rotator cuff tears with concomitant shoulder stiffness in elderly patients. Rotator cuff tears in the elderly has insidious onset and long course. The etiology and pathological mechanism are not clear, so it is difficult to conduct early prevention. Therefore, seeking effective treatment plan is an urgent clinical problem at present. **Methods:** In a single-center trial, we randomly assigned patients aged over 60 years old with rotator cuff tear and shoulder adhesion into observation group and control group in a 1:1 ratio. The observation group was treated with injection in the glenohumeral joint cavity and subacromial bursa by ultrasonic guidance, then combined with neuromuscular control training in stages. The control group was treated with oral medication, physiotherapy and exercise rehabilitation. Patients received 5 weeks of care. Clinical outcomes were assessed at baseline, 1 week, 1 month, and 3 months after treatment. The primary outcome was the intensity of shoulder pain on a visual analogue scale (ranging from 0 to 10, with higher scores indicating more severe pain). Secondary outcomes including the scores on the University of California at Los Angeles shoulder function (UCLA) and active range of motion (AROM) including flexion, abduction, and external rotation with the arm at the side. **Results:** From September 2021 to March 2024, a total of 60 patients were enrolled, with 30 in each group. There were no statistically significant differences in baseline characteristics between the two groups ($P > 0.05$). At the first week, the first month, and 3th months after treatment, the primary outcome of the shoulder pain intensity score was significantly superior to the control group ($P < 0.05$). Secondary outcomes including the UCLA score and joint range of motion at 3 months were in the same direction as the primary outcome ($P < 0.05$). **Conclusions:** In this single-center trial involving patients with aged over 60 years old with rotator cuff injury and shoulder adhesion, neuromuscular control training

combined with intro-articular injection can continuously relieve pain, significantly improve joint mobility and shoulder function at 3 months of follow-up.

Keywords:

Rotator Cuff Tear, Shoulder Stiffness, Neuromuscular Control Training, Injection

1. Introduction

Rotator cuff tear is a common cause of shoulder pain and dysfunction, and its incidence is positively correlated with increasing age, with a prevalence of 26% in those over 60 years and rising to 65% over 80 years [1]. Because of multiple factors such as trauma, inflammation and pain, rotator cuff injuries are often associated with shoulder adhesions [2]. Elderly patients often prefer conservative treatment due to organ function decline, multiple comorbidities, and low surgical compliance [3]. Currently, there is no consensus on the concrete treatment for rotator cuff tears with shoulder stiffness [4]

More studies have confirmed that Ultrasound-guided application of corticosteroid hormone and sodium hyaluronate injection for rotator cuff injury can relieve pain and improve shoulder mobility in the short term [5,6,7]. However, some scholars have pointed out that corticosteroid injections can provide rapid pain relief in elderly patients with rotator cuff injuries but may lead to recurrent symptoms as the drug effect diminishes, with poor long-term functional outcomes [7,8], and the targeted exercise training can help to improve the shoulder joint function and consolidate the efficacy [9,10]. Based on this, the present study explores the efficacy of combining ultrasound-guided injections into the glenohumeral joint and subacromial bursa with phased neuromuscular control training in the treatment of elderly patients with rotator cuff injuries and shoulder joint adhesions.

2. Methods

2.1. Trial Design

This investigator-initiated, prospective, randomized, controlled trial was performed at Fuqing City Hospital of Fujian Province, Fuqing Fujian, China. The research protocol was approved by the local ethics board and was funded by Fuzhou Health and Wellness Youth and Middle-aged Scientific Research Project (2021-S-wq37); there was no industry involvement in the trial. The authors vouch for the completeness and accuracy of the data and for the fidelity of the trial to the protocol. An informed consent form was signed by all participants in the study.

2.2. Enrollment and Randomization

From September 2021 through March 2024, patients were recruited from rehabilitation department at our institution. Eligible patients were over 60 years, had a history over 3 months, diagnosed with rotator cuff tears and shoulder joint adhesions confirmed by ultrasound or MRI, and had shoulder joint movement limitations (passive flexion and elevation $<120^\circ$, external rotation with the arm at the side $<30^\circ$, or internal rotation below the L3 level). Exclusion criteria were had massive rotator cuff tears (>5 cm) and moderate to severe osteoarthritis of the glenohumeral joint,

shoulder fractures or surgeries, allergy to lidocaine hydrochloride injection, or Severe diseases of the liver, kidney, hematopoietic or endocrine system.

Patients were informed that they would provide written informed consent to undergo randomization and comply with systematic rehabilitation treatment. Patients were randomly assigned in a 1:1 ratio to an observation group and a control group.

2.3. Trial Interventions

Patients in the observation group underwent ultrasound-guided injections into the glenohumeral joint and subacromial bursa, followed by phased neuromuscular control training. Patients were seated, and the affected shoulder was scanned using ultrasound. After local disinfection and preparation, the anterior gap of the shoulder joint was located with ultrasound. Under ultrasound guidance, a needle was inserted 1.0 cm lateral to the coracoid process into the glenohumeral joint cavity, and a small amount of treatment solution (5 ml of 0.9% sodium chloride solution + 1 ml of compound betamethasone injection + 2 ml of lidocaine hydrochloride injection) was injected. After confirming that the treatment solution entered the joint capsule, the remaining solution was injected, followed by 2.5 ml of sodium hyaluronate injection. The subacromial bursa was then located using ultrasound, and the treatment solution (2 ml of 0.9% sodium chloride solution + 1 ml of compound betamethasone injection + 2 ml of lidocaine hydrochloride injection) was injected under ultrasound guidance. The injection site was covered with sterile adhesive tape. During the first week, the above solution was injected, and for the subsequent 4 weeks, only sodium hyaluronate was injected into the glenohumeral joint cavity. Phased neuromuscular control training was conducted during the injection period [11,12,13]. First Phase (1–7 days post-injection): ① Massage and stretching to relax the tense muscles, joint capsule, ligaments, and tendon tissues around the shoulder joint; ② Perform passive movements within the patient's tolerable range, followed by active-assisted exercises for shoulder joint flexion, extension, adduction, and abduction range of motion training, as well as contralateral shoulder tapping and pendulum-like exercises, twice daily for 10–15 minutes. Second Phase (8–21 days post-injection): ① Closed-chain training (see Figure 1): Using a 25 cm diameter Pilates ball below shoulder level, the affected hand presses the ball against the wall to perform shoulder flexion and external rotation movements, while the affected elbow pushes the ball against the wall to perform shoulder extension and abduction movements, twice daily for 5 minutes. ② Isometric resistance training (see Figure 2): Using a Thera-band resistance band, perform isometric resistance exercises for shoulder flexion, extension, adduction, abduction, internal rotation, and external rotation within a pain-free range. Each movement is held for 6 seconds, 10 repetitions per set, twice daily. ③ Shoulder girdle PNF (Proprioceptive Neuromuscular Facilitation) stretching: Using the stretching mode of the shoulder girdle, perform manual resistance exercises for the scapula in the following directions: forward and upward, backward and downward, backward and upward, and forward and downward which repeat 10–15 times. During the treatment, use clear and concise commands while applying techniques such as isotonic contraction, contract-relax, hold-relax, and rhythmic stabilization. Each session lasts 10 minutes, performed every other day, three times per week. Third Phase (22–35 days post-injection): ① Proprioception training (see Figure 3): The affected hand holds a stick and slowly traces the numbers 0–9 on a wall. If this is completed with ease, progress to attaching a 0.5–1 kg sandbag to the wrist of the affected side while performing the tracing exercises, twice daily for 5–10 minutes.

② Progressive isotonic resistance training (see Figure 4): Using resistance bands of varying strengths, perform isotonic resistance exercises for shoulder flexion, extension, adduction, abduction, and internal and external rotation within the scapular plane at 90° abduction. Each movement is held at the end range of motion for more than 10 seconds, twice daily for 5–10 minutes. ③ Weighted training: Hold dumbbells in both hands and perform open-chain muscle strength exercises in different positions and angles within a pain-free range. Gradually increase the load in all directions, twice daily for 5–10 minutes.

Patients in the control group were prescribed oral celecoxib capsules (200 mg per dose, every 12 hours) for 5 weeks. They also received 20-minute sessions of medium-frequency interference current therapy and shortwave therapy every other day, 3 times per week for 5 weeks. Rehabilitation training included passive and active exercises, such as pendulum exercises, wall climbing, pulley-assisted movements, and stick exercises, performed twice daily for 15–20 minutes each session over 5 weeks.



Figure 1 Closed joint stabilization training.



Figure 2 Isometric resistance training.



Figure 3 Proprioception training.



Figure 4 Progressive equal-tension resistance training.

2.4. Outcomes

The efficacy of rehabilitation was assessed by a designated professional at baseline, 1 week, 1 month, and 3 months after treatment. The primary outcome was the intensity of shoulder pain on a visual analogue scale (ranging from 0 to 10, with higher scores indicating more severe pain) at 1 week, 1 month, 3 months after enrollment. Secondary outcomes included the scores on the University of California at Los Angeles shoulder function (UCLA) and active range of motion (AROM) including flexion, abduction, and external rotation with the arm at the side. The University of California at Los Angeles (UCLA) Shoulder Score was used to evaluate

shoulder function, including pain, function, forward flexion range of motion, forward flexion manual muscle testing, and patient satisfaction [14]. The total score is 35 points, with higher scores indicating better shoulder function. The degree of AROM was measured using a goniometer.

2.5. Statistical Analysis

The categorical data between the two groups were compared using the chi-square test. Measurement data following a normal distribution were analyzed using the t-test, while data with a non-normal distribution were analyzed using the rank-sum test. Repeated measurement data were analyzed using repeated measures ANOVA. A value of $P < 0.05$ was considered statistically significant. All data were analyzed using SPSS 22.0 statistical software.

3. Results

3.1. Patients

A total of 60 patients were enrolled, with 30 assigned to an observation group and 30 to a control group. Each group. Both groups were entered into the follow-up visit. In the observation group, there were 5 males and 25 females; 13 cases involved the left shoulder and 17 the right shoulder; the age range was 60–86 years, with an average of (68.97 ± 7.26) years; the disease duration ranged from 3 to 36 months, with an average of (8.67 ± 7.00) months. In the control group, there were 7 males and 23 females; 19 cases involved the left shoulder and 11 the right shoulder; the age range was 60–77 years, with an average of (66.97 ± 5.37) years; the disease duration ranged from 3 to 24 months, with an average of (6.83 ± 5.22) months. There were no statistically significant differences in baseline characteristics between the two groups ($P > 0.05$).

3.2. VAS

Significant differences between the two groups were determined by the test of group-by-time interaction ($P < 0.001$) and the following post hoc test ($P < 0.001$ for all), suggesting that the Observation group showed more significant improvements compared to the Control group over time. Pairwise comparisons at each time point showed that the VAS scores in the Observation group were significantly lower than those in the Control group at every follow-up time point ($P < 0.001$), indicating a more effective treatment outcome in the Observation group. For intragroup comparisons, a significant improvement in VAS scores was observed as early as 1 week after treatment in both the Observation ($P < 0.001$) and Control ($P < 0.001$) groups, and these improvements continued to increase significantly at 1 month and 3 months after treatment ($P < 0.001$ for all). At the final follow-up, the VAS score was 0.30 ± 0.36 in the Observation group and 1.90 ± 0.72 in the Control group ($P < 0.001$), indicating a more effective pain relief in the Observation group (Table 1).

Table1. Comparison of VAS Scores Before and After Treatment at Different Time Points Between the Two Groups of Patients.

Group	Number of Cases	Before Treatment	1 Week After Treatment	1 Month After Treatment	3 Months After Treatment	F-value	P-value
Observation Group	30	6.75 ± 0.58	$3.23 \pm 0.69^*$	$1.28 \pm 0.47^*$	$0.30 \pm 0.36^*$	832.151	0.000

Control Group	30	6.35±0.6 ₂	5.25±0.72*	3.63±0.69*	1.90±0.72*	237.998	0.000
t-value		1.291	11.096	15.381	10.827		
P-value		0.071	0.000	0.000	0.000		

*Note: * indicates a statistically significant difference compared to the baseline (before treatment).

3.3. UCLA

Similar to the changes in VAS scores, significant differences in UCLA scores were detected according to the group-by-time interaction ($P < 0.001$ for all) with a post hoc test between the two groups ($P < 0.001$ for all). At each follow-up time point, the UCLA scores in the Observation group were significantly higher than those in the Control group ($P < 0.001$). At the final follow-up, the UCLA score reached 31.77 ± 2.90 in the Observation group and 25.10 ± 2.51 in the Control group ($P < 0.001$), suggesting that the Observation group had a more pronounced and sustained improvement compared to the Control group (Table 2).

Table 2. Comparison of UCLA Scores Before and After Treatment at Different Time Points Between the Two Groups of Patients.

Group	Number of Cases	Before Treatment	1 Week After Treatment	1 Month After Treatment	3 Months After Treatment	F-value	P-value
Observation Group	30	10.83±1.86	21.13±2.67*	26.87±2.85*	31.77±2.90*	358.159	0.000
Control Group	30	11.33±1.92	14.90±2.16*	20.33±2.32*	25.10±2.51*	219.485	0.000
t-value		1.025	-9.939	-9.731	-9.526		
P-value		0.309	0.000	0.000	0.000		

*Note: * indicates a statistically significant difference compared to the baseline (before treatment).

3.4. AROM

Regarding the AROM scores, significant improvements were observed in both groups over time, but the Observation group showed more substantial gains compared to the Control group. For forward flexion, the Observation group reached $148.43 \pm 12.21^\circ$ at 3 months, while the Control group reached $131.37 \pm 12.63^\circ$ ($P < 0.001$). Similar trends were observed for abduction and external rotation, with the Observation group consistently outperforming the Control group at each follow-up time point ($P < 0.05$ for all) (Table 3).

Table 3. Comparison of AROM Scores Before and After Treatment at Different Time Points Between the Two Groups of Patients.

Group	Number of Cases	Before Treatment	1 Week After Treatment	1 Month After Treatment	3 Months After Treatment	F-value	P-value
Forward Flexion ($^\circ$)							
Observation Group	30	91.17±12.98	109.63±16.23*	129.83±16.37*	148.43±12.21*	86.869	0.000

Control Group	30	91.77±16.67	98.37±15.04*	114.03±14.78*	131.37±12.63*	42.424	0.000
t-value		0.156	-2.789	-3.923	-5.323		
P-value		0.877	0.007	0.000	0.000		
Abduction (°)							
Observation Group	30	73.60±15.96	91.43±13.24*	107.63±15.61*	128.13±16.22*	69.2	0.000
Control Group	30	78.90±12.50	84.50±10.10*	95.03±8.56*	108.57±9.19*	49.158	0.000
t-value		1.432	-2.281	-3.877	-5.75		
P-value		0.158	0.027	0.000	0.000		
External Rotation (°)							
Observation Group	30	15.93±8.34	29.53±11.79*	42.60±9.31*	56.00±8.65*	96.000	0.000
Control Group	30	20.20±8.86	23.53±7.90*	37.00±7.83*	50.70±7.76*	88.834	0.000
t-value		1.920	-2.328	-2.521	-2.497		
P-value		0.060	0.023	0.014	0.015		

*Note: * indicates a statistically significant difference compared to the baseline (before treatment).

These outcomes indicate that patients in the Observation group benefited more from the treatment compared to those in the Control group, with faster and more significant improvements in VAS, UCLA, and AROM scores. The effect of the treatment in the Observation group was not only more pronounced but also sustained throughout the 3-month follow-up period. No complications occurred including infection, vascular and nerve injury in either group.

4. Discussion

The rotator cuff plays a vital role in maintaining static and dynamic stability of the glenohumeral joint, enabling various postures of the upper arm and completing various movements of the shoulder joint [15,16]. Rotator cuff injuries with shoulder joint adhesion are common in the elderly. The main symptoms are peripheral shoulder pain, weakness and joint dysfunction, and if untreated, can lead to significant functional impairment and reduced quality of life. Elderly patients often exhibit complex etiologies, insidious symptoms, and a gradual onset of tendon degeneration, making early prevention and intervention challenging [17]. Patients have affected limb movement due to pain, long course of disease because of joint loss, muscle atrophy secondary to muscle fat infiltration leading to shoulder stiffness [18]. In addition, local inflammatory response of rotator cuff injury and increased cellulose generation will further aggravate the adhesion of the shoulder joint [19]. The cuff is located on the surface of the rotator cuff, the deep surface of the acromion and deltoid, and is one of the largest burdens in the human body. Ko et al. [20] analyzed the high levels of IL-1, IL-6 and TNF- α in acromial descending capsule tissue and recruitment of myofibroblasts were associated with rotator cuff injury with shoulder adhesion lesions, which were important causes of shoulder pain and stiffness in patients with rotator cuff disease.

Gong Shiguo et al. [21] demonstrated that injecting betamethasone and sodium hyaluronate into the joint cavity and subacromial bursa effectively controls inflammation, relieves pain, and improves shoulder joint range of motion in patients with rotator cuff injuries. Compound betamethasone is a steroid-based compound preparation, with its main components being betamethasone sodium phosphate and betamethasone dipropionate. The water-soluble betamethasone sodium phosphate is quickly absorbed after injection, providing rapid effects, while the slightly soluble betamethasone dipropionate is absorbed slowly, offering prolonged action and long-term inflammation control. This avoids the gastrointestinal side effects commonly associated with long-term oral non-steroidal anti-inflammatory drugs (NSAIDs) [22,23]. Sodium hyaluronate, a high-molecular-weight polysaccharide biomaterial, is a key component of joint synovial fluid, cartilage, and connective tissue. Injecting sodium hyaluronate into the joint cavity provides lubrication and nourishment to the articular cartilage, reduces adhesions in the joint and surrounding tendon bursa tissues, and improves joint function [24,25]. In this study, during the first week, musculoskeletal ultrasound was used to precisely guide the injection of betamethasone, lidocaine hydrochloride, and sodium hyaluronate into the glenohumeral joint cavity and subacromial bursa. For the subsequent four weeks, only sodium hyaluronate was injected into the glenohumeral joint cavity. This approach achieved rapid short-term inflammation control and pain relief, preventing elderly patients from avoiding exercise therapy due to shoulder pain and laying the foundation for early initiation of systematic rehabilitation training.

Neuromuscular control primarily includes proprioception, muscle activity, and postural balance. It is a complex process in which the central nervous system integrates sensory input from visual, somatosensory, and vestibular systems to generate motor feedback. This represents an unconscious interaction between the nervous system and the musculoskeletal system [26]. Studies have shown that after rotator cuff injuries, the muscles around the scapular girdle exhibit low activation levels, and proprioception in structures such as the glenoid labrum, joint capsule ligaments, and muscles is reduced [27,28]. This leads to decreased sensory input, reduced joint stability, and weakened neuromuscular control, ultimately resulting in recurrent rotator cuff injuries. Previous studies have confirmed that patients with rotator cuff injuries can improve their neuromuscular control abilities through phased training involving varying levels of muscle strength, joint stability, and proprioception. This helps restore mechanical balance and significantly promotes the recovery of shoulder joint function [29,30].

5. Conclusions

This study took into account the emotional response to pain and fear of movement commonly experienced by elderly patients with chronic conditions. A slow and gradual approach was adopted to progressively increase neuromuscular control training in phases, minimizing the risk of reinjury during rehabilitation. In the early phase, the focus was on soft tissue relaxation and adhesion release, combined with joint range of motion exercises. Exercises were initiated below the shoulder level, emphasizing low-load, low-intensity, and pain-free movements. In the mid-phase, closed-chain joint stability training using a Pilates ball was introduced to stimulate joint proprioceptors. This was gradually progressed to isometric resistance strength training using Thera-Band resistance bands to enhance the strength and endurance of the scapular girdle muscles, thereby reconstructing the neuromuscular control

mechanism for proprioception around the shoulder joint. Scapular PNF (Proprioceptive Neuromuscular Facilitation) training was also applied to activate the deep muscles of the shoulder, improve the stability of the scapulothoracic joint, and enhance the coordinated movement of the shoulder joint and upper limb [31]. In the later phase, based on resistance training for joint stability, proprioception training and full-range open-chain strength and endurance training with weights were further intensified to promote the recovery of shoulder joint function. Follow-up results at 1 week, 1 month, and 3 months after treatment showed that the VAS scores of patients in the observation group were significantly reduced, while shoulder joint range of motion and UCLA scores were markedly improved. Adhesions in the shoulder joint were effectively released, and the strength and endurance of the rotator cuff and scapular girdle muscles were enhanced. Compared to the control group, the observation group exhibited significantly better improvements in shoulder joint function, with patients showing high acceptance and satisfaction with the treatment.

This study has some limitations: the small sample size, short follow-up time and whether there is a difference in long-term efficacy between the two groups needs further investigation; individual deviations in the design and application of patient exercise program may affect the efficacy, and the lack of detailed imaging evaluation of the treatment effect.

We found that neuromuscular control training combined with joint cavity injection in the treatment of elderly rotator cuff injury and shoulder adhesion can effectively relieve pain, improve shoulder function, has the advantages of accurate treatment, sustained and stable efficacy, and high patient satisfaction, which is worthy of clinical promotion and application.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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